HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND
U S ARMY

TECHNICAL REPORT

EP-151

TEMPORARY HEARING LOSSES FOR PROTECTED AND UNPROTECTED EARS AS A FUNCTION OF EXPOSURE TIME TO CONTINUOUS AND IMPULSE NOISE

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

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NATICK, MASSACHUSETTS

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Alexander Cohen, Ph. D.
Research Psychologist

PSYCHOLOGY BRANCH

June 1961

Project Reference:
7X95-01-001

FOREWORD

THE ADVERSE EFFECTS OF EXTREME NOISE EXPOSURE ON MAN'S HEARING ABILITY ARE WELL RECOGNIZED. HOWEVER, MORE INFORMATION IS NEEDED REGARDING THE POTENCY OF DIFFERENT TYPES OF NOISE FOR PRODUCING HEARING IMPAIRMENTS AND THE ABILITY OF PROTECTIVE ITEMS TO OFFSET SUCH EFFECTS. THE PRESENT INVESTIGATION STUDIED THE TEMPORARY HEARING LOSSES RESULTING FROM CONTROLLED EXPOSURE TO TWO TYPES OF NOISE WHICH ARE PREDOMINANT IN COMBAT SITUATIONS. THE EFFECTIVENESS OF THE NOISE PROTECTION GIVEN BY A CONVENTIONAL HELMET ITEM UNDER THESE EXPOSURE CONDITIONS WAS ALSO EVALUATED.

AUSTIN HENSCHEL
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CONTENTS

ABSTRACT

TEMPORARY HEARING LOSSES FOR FREQUENCIES 250 TO 8000 CPS WERE NOTED FOR BARE AND PROTECTED EARS (CVC HELMET) AFTER 6-, 12-, AND 18-MINUTE EXPOSURES TO IMPULSE NOISE (RECORDED 30-CAL. MACHINE-GUN FIRE) AND CONTINUOUS WIDEBAND NOISE OF COMPARABLE ENERGY. THRESHOLD LOSSES FOR BOTH TYPES OF NOISE WERE GENERALLY CONFINED TO FREQUENCIES ABOVE 1000 CPS AND TENDED TO BECOME GREATER WITH INCREASING EXPOSURE TIME. CONTINUOUS NOISE CAUSED GREATER HEARING LOSSES THAN THE IMPULSE NOISE UNDER BARE EAR CONDITIONS FOR THE THREE EXPOSURE TIMES. A COMPARISON OF THESE LOSSES AGAINST THOSE NOTED WHEN USING THE HELMET INDICATED THAT THE HELMET GAVE SIGNIFICANT PROTECTION AGAINST CONTINUOUS NOISE BUT LITTLE PROTECTION AGAINST IMPULSE NOISE.

A SECOND EXPERIMENT STUDIED THE RECOVERY OF 4000 CPS THRESHOLD LOSSES FOR A 20-MINUTE PERIOD AFTER EXPOSURE TO THE NOISE CONDITIONS CITED ABOVE. ESPECIALLY FOR THE LONGER EXPOSURE TIMES (12 AND 18 MINUTES), THRESHOLD RECOVERY FROM BARE EAR EXPOSURES TO CONTINUOUS NOISE WAS SLOWER THAN THAT NOTED FOR IMPULSE NOISE. AS COMPARED WITH THE BARE EARS, WEARING THE HELMET PROVIDED FASTER RATES OF RECOVERY FROM LOSSES DUE TO CONTINUOUS NOISE EXPOSURES BUT DID NOT FACILITATE RECOVERY FROM LOSSES DUE TO IMPULSE NOISE.

TEMPORARY HEARING LOSSES FOR PROTECTED AND UNPROTECTED EARS AS A FUNCTION OF EXPOSURE TIME TO CONTINUOUS AND IMPULSE NOISE

INTRODUCTION

MILITARY OPERATIONAL SITUATIONS EXPOSE THE SOLDIER TO BOTH CONTINUOUS AND IMPULSE NOISE. THE NOISE PRODUCED BY THE ENGINES OF ARMORED VEHICLES AND AIRCRAFT IS AN EXAMPLE OF THE CONTINUOUS COMPONENT; THE FIRING OF WEAPONS EXEMPLIFIES THE IMPULSE COMPONENT. IT HAS BEEN WELL ESTABLISHED THAT BOTH TYPES CAN CAUSE HEARING LOSSES (5, 7, 10, 12), BREAKDOWNS IN VOICE COMMUNICATIONS (5, 9, 12), FATIGUE (2, 5, 7), AND OTHER ADVERSE EFFECTS (2, 7, 16) WHICH MAY REDUCE THE EFFICIENCY OF COMBAT PERSONNEL. ONLY RECENTLY, HOWEVER, HAVE THE DETRIMENTAL EFFECTS OF CONTINUOUS AND IMPULSE NOISE BEEN STUDIED ON A COMPARATIVE BASIS. USING TEMPORARY POST-EXPOSURE LOSSES IN HEARING* AS AN INDEX OF ACOUSTIC TRAUMA, IT HAS BEEN FOUND THAT IMPULSE NOISE IS LESS NOXIOUS THAN AN EQUIVALENT AMOUNT OF CONTINUOUS NOISE (14). ENLARGING UPON THE LATTER DATA, THE PRESENT INVESTIGATION WAS CONCERNED WITH THE TEMPORARY HEARING LOSSES FOLLOWING VARIOUS EXPOSURE TIMES TO COMPARABLE AMOUNTS OF CONTINUOUS AND IMPULSE NOISE. IN ADDITION, THE PROTECTION FURNISHED BY A COMBAT VEHICLE CREWMAN'S HELMET (CVC-T56-6)** AGAINST SUCH LOSSES WAS ASSESSED UNDER THE DIFFERENT CONDITIONS OF NOISE EXPOSURE.

EXPERIMENT 1
MAGNITUDE OF HEARING LOSS FOR DIFFERENT FREQUENCIES

1. METHODOLOGY AND APPARATUS

A. CONDITIONS OF NOISE EXPOSURE AND AUDIOMETRIC TECHNIQUE

TEMPORARY SHIFTS IN HEARING THRESHOLDS WERE STUDIED INITIALLY FOR FREQUENCIES 250 TO 8000 CPS FOLLOWING 12 DIFFERENT NOISE EXPOSURE CONDITIONS. THESE CONDITIONS REPRESENTED ALL COMBINATIONS OF 2 TYPES OF NOISE (IMPULSE, CONTINUOUS), 3 EXPOSURE TIMES (6, 12, AND 18 MINUTES), AND 2 DEGREES OF EAR PROTECTION (BARE, CVC HELMET). THRESHOLD SHIFTS WERE DETERMINED FROM THE DIFFERENCES BETWEEN AUDIOGRAMS TAKEN JUST BEFORE AND IMMEDIATELY AFTER EACH EXPOSURE TO NOISE. AUDIOGRAMS WERE OBTAINED

*AS THE TERM IMPLIES, TEMPORARY HEARING LOSS REFERS TO THOSE HEARING IMPAIRMENTS WHICH ARE NOT PERMANENT IN TIME. GENERALLY, ANY INDIVIDUAL EXPOSED TO MODERATELY INTENSE NOISE WILL SHOW A LOSS IN HEARING AS REFLECTED BY SHIFTS IN THRESHOLDS FOR HEARING DIFFERENT FREQUENCIES OF SOUND. UPON REMOVAL FROM THE NOISE, THESE THRESHOLD SHIFTS WILL DIMINISH AND HEARING WILL RETURN TO NORMAL. THE MAGNITUDES OF THE THRESHOLD LOSSES AND/OR THE TIME NECESSARY TO RECOVER FROM SUCH LOSSES ARE FREQUENTLY USED TO EVALUATE THE POTENCY OF DIFFERENT NOISE EXPOSURE CONDITIONS FOR PRODUCING PERMANENT HEARING DAMAGE.

**A DESCRIPTION OF THIS HELMET CAN BE FOUND IN REFERENCE (4). IT IS TO BE REFERRED TO HEREINAFTER AS CVC HELMET.

BY MEANS OF A BÉKÉSY TECHNIQUE (3) IN WHICH A TEST-TONE WAS CONTINUOUSLY VARIED ACROSS THE FREQUENCY RANGE 100 TO 10000 CPS. THIS SIGNAL WAS PRODUCED BY A GRASON-STADLER OSCILLATOR (MODEL 950D) WHOSE TUNING DIAL WAS GEARED TO A 1 RMP REVERSIBLE MOTOR. BY MEANS OF THE REMOTE SWITCH ON A GRASON-STADLER MOTOR-DRIVEN RECORDING ATTENUATOR (MODEL E3262A), THE SUBJECT CONTINUOUSLY CONTROLLED THE SIGNAL INTENSITY SO AS TO OSCILLATE BETWEEN JUST-HEARING AND JUST-NOT-HEARING THE TEST TONE. THE ATTENUATOR GAVE A 2.5 DB/SEC RATE OF SIGNAL ATTENUATION OVER A 100 DB INTENSITY RANGE.

THE SUBJECTS' INTENSITY SETTINGS WERE PLOTTED AGAINST TEST-TONE FREQUENCY ON THE RECORDING SECTION OF THE ATTENUATOR. A TYPICAL PLOT IS SHOWN IN FIGURE 1. AS INDICATED IN THIS GRAPH, THE MIDPOINTS BETWEEN THE PEAKS (POINTS OF JUST-HEARING THE SIGNAL) AND TROUGHS (POINTS OF JUST-NOT-HEARING THE SIGNAL) WERE CONNECTED BY STRAIGHT LINES TO ESTABLISH THE THRESHOLD CURVE ACROSS THE SPECIFIED FREQUENCY RANGE.

B. SOURCES OF IMPULSE AND CONTINUOUS NOISE

THE SOURCE OF REPEATED IMPULSE NOISE WAS THE SOUND PRODUCED BY FIRING A 30 CAL. AIR-COOLED MACHINE GUN. THIS NOISE WAS ORIGINALLY RECORDED ON TAPE AT AN INFILTRATION TRAINING COURSE WHILE THE WEAPON WAS IN USE. IN THE RECORDING SITUATION, THE OUTPUT OF A MASSA MICROPHONE (MODEL 141F), PLACED JUST BEHIND THE GUNNER'S RIGHT EAR, WAS LED TO BOTH CHANNELS OF AN AMPEX DUAL-CHANNEL TAPE RECORDER (MODEL 351). THE TAPE SPEED DURING RECORDING WAS 15 IN/SEC. THE PEAK LEVELS OF THE FIRING NOISE AT THE GUNNER'S EAR WERE 133 ±2 DB* (RE 0.0002 DYNE/CM^2) AS MEASURED ON A GENERAL RADIO IMPACT NOISE METER (MODEL 1556A) WHICH WAS COUPLED TO A GENERAL RADIO SOUND LEVEL METER (MODEL 1551B).

THE ORIGINAL RECORDING CONTAINED BURSTS OF 3 AND 4 ROUNDS OF GUNFIRE, AND THE TOTAL RECORDING TIME WAS APPROXIMATELY 4 MINUTES. SELECTED SEGMENTS OF THIS TAPE WERE SUBSEQUENTLY SPLICED TOGETHER TO FORM A CLOSED LOOP THROUGH THE TAPE DECK. THUS, THE RECORDED SOUNDS COULD BE PLAYED BACK CONTINUOUSLY FOR ANY DESIRED LENGTH OF TIME. BY FEEDING THIS OUTPUT TO ANOTHER DUAL-CHANNEL TAPE RECORDER (AMPEX, MODEL 351) WITH CONTINUOUSLY MOVING TAPE, A FINAL RECORDING WAS OBTAINED WHICH COULD REPRODUCE

*THESE PEAK VALUES ARE LOWER THAN THOSE NOTED IN A SURVEY OF THE NOISE GENERATED BY THE 30 CAL. MACHINE GUN, AS WELL AS THOSE OF OTHER WEAPONS (1). WHILE THIS DISCREPANCY MAY REFLECT THE TENDENCY OF THE PEAK READING METER TO UNDERESTIMATE THE LEVELS OF IMPULSE SOUNDS, SUBSEQUENT MEASUREMENTS OF THE IMPULSE NOISE WITH A CALIBRATED OSCILLOSCOPE INDICATED PEAK VALUES WHICH WERE IN AGREEMENT WITH THE METER READINGS. THE DIFFERENCE MAY BE DUE TO THE FACT THAT THE MACHINE GUN USED IN THE PRESENT STUDY WAS FIXED TO A MOUNT WHICH WAS IMBEDDED IN A 3 FOOT HIGH CONCRETE PLATFORM. IN THE NOISE SURVEY, MEASUREMENTS WERE TAKEN ON GUNS WHICH WERE MOUNTED ON TANKS AND CONVENTIONAL TRIPODS. PRESUMABLY THE LATTER CONDITIONS MAY HAVE ENHANCED THE NOISE LEVELS OF THE WEAPON.

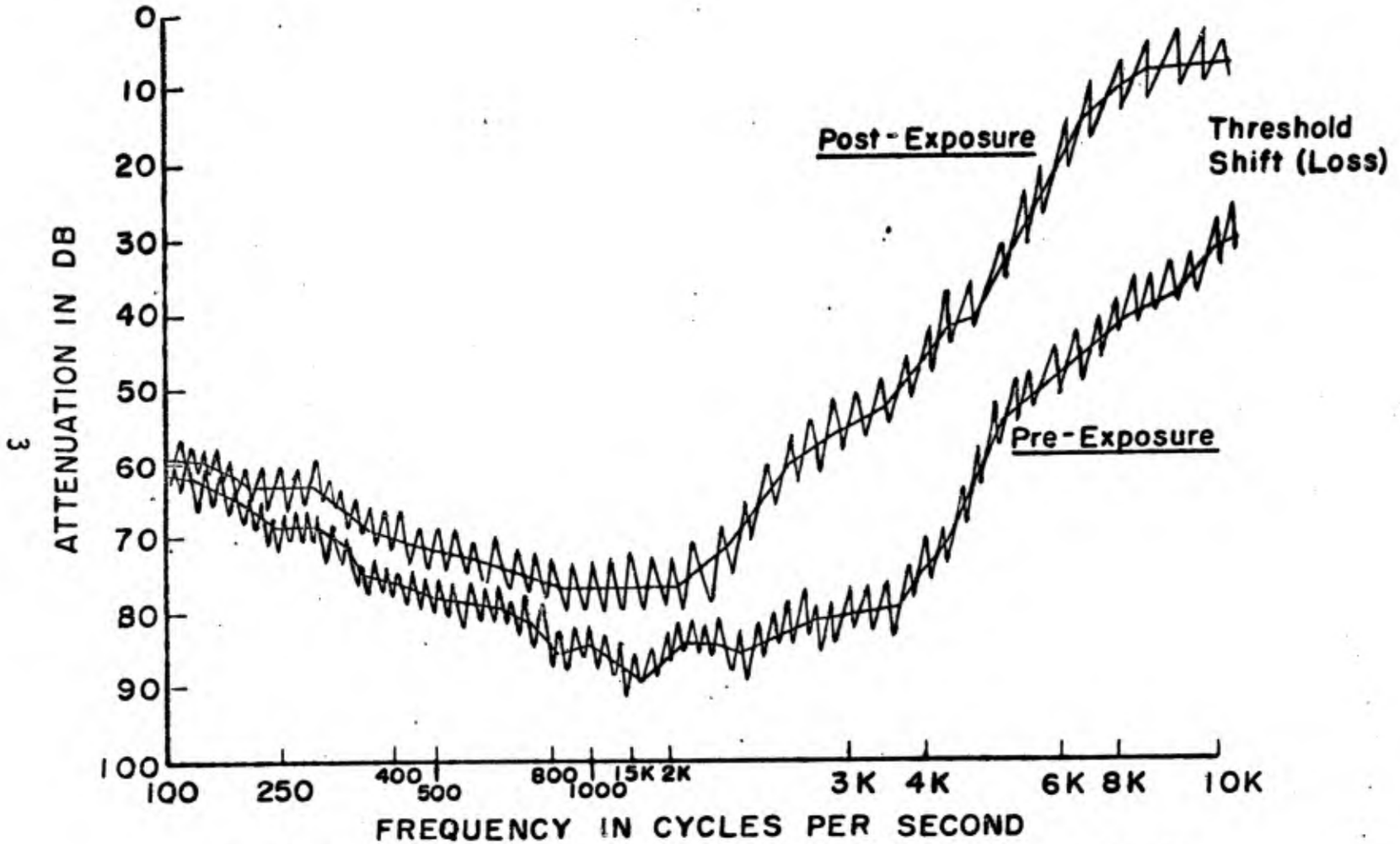

FIGURE 1: EXAMPLE OF AUDIOGRAMS OBTAINED BEFORE AND AFTER NOISE EXPOSURE.

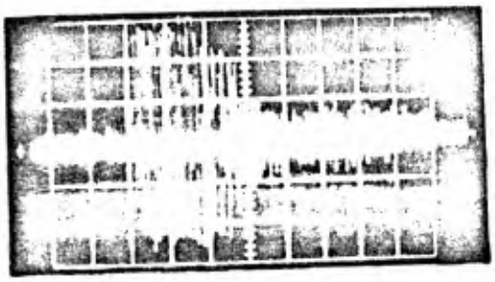

FIGURE 2: OSCILLOGRAPH TRACING OF BURST OF IMPULSE NOISE. THE TIME BASE (HORIZONTAL AXIS) IS 20 MILLESEC/DIV.

MACHINE-GUN FIRE FOR PERIODS AS LONG AS 18 MINUTES. ANALYSES OF THIS TAPE WITH A BRUSH GRAPHIC RECORDER (MARK 11) AND HEWLETT-PACKARD OSCILLOSCOPE (MODEL 152A) SHOWED THAT 136 ±1 BURSTS OCCURRED PER MINUTE WITH THE DURATION OF THE BURST AVERAGING 60 MILLESEC (SEE FIG. 2).

IN THE ACTUAL TESTING SITUATION (FIG. 3), THE RECORDED GUNFIRE WAS PLAYED BACK THROUGH TWO ACRO-SOUND 60-WATT POWER AMPLIFIERS (MARK 11) AND FED TO ONE ALTEC LANSING (602A) AND TWO ACOUSTIC RESEARCH (AR-2) SPEAKERS WHICH WERE LOCATED IN A SOUND-DEADENED ROOM. THE LOUDSPEAKERS FORMED AN EQUILATERAL TRIANGLE (LENGTH OF EACH SIDE: 68 INCHES) AND DIRECTED THEIR SOUND INWARD TOWARD THE CENTER OF THE TRIANGLE WHERE THE SUBJECT WAS SEATED WITH HIS EARS AT APPROXIMATELY THE LEVEL OF THE SPEAKERS. THIS REPRODUCTION SYSTEM YIELDED BURST LEVELS OF FIRING NOISE WHICH AVERAGED 128 DB AT THE LISTENER'S EARS, INDIVIDUAL BURSTS RANGING FROM 125 TO 131 DB. LIMITATIONS OF THE AMPLIFIER AND SPEAKER SYSTEMS PREVENTED A BETTER CORRESPONDENCE BEING OBTAINED WITH THE ORIGINAL BURST LEVEL VALUES NOTED ABOVE. THE INTERVALS BETWEEN BURSTS IN THE TEST SITUATION AVERAGED 75 DB IN INTENSITY. COMPUTATIONS WHICH TOOK INTO ACCOUNT BURST LEVEL, INTER-BURST LEVEL, AND THE AMOUNT OF BURST AND INTER-BURST TIME PER MINUTE INDICATED THAT THE AVERAGE SOUND INTENSITY REACHING THE EAR FOR EACH MINUTE OF EXPOSURE WAS 111 DB. THESE COMPUTATIONS ARE DESCRIBED IN THE APPENDIX.

THE CONTINUOUS NOISE SOURCE WAS THE OUTPUT OF A GRASON-STADLER NOISE GENERATOR (MODEL 455B). THIS OUTPUT, BY MEANS OF A SWITCHING ARRANGEMENT (SWITCH A - FIG. 3), WAS SUPPLIED TO THE AMPLIFIER AND LOUDSPEAKER SYSTEM ALREADY DESCRIBED. THE OVERALL NOISE LEVEL OF THE CONTINUOUS NOISE WAS HELD CONSTANT AT 111 DB AT THE OBSERVER'S EARS WHICH MATCHED THE AVERAGE INTENSITY LEVEL FOR THE IMPULSE NOISE.

THE INTENSITY READINGS FOR THE IMPULSE NOISE IN THE SOUND-DEADENED ROOM WERE NOTED ON THE IMPACT NOISE METER AND SOUND LEVEL METER. INSERTION OF A GENERAL RADIO OCTAVE-BAND NOISE ANALYZER (MODEL 1550S) BETWEEN THESE TWO METERS GAVE A DESCRIPTION OF THE FIRING NOISE IN OCTAVE BANDS.*

*ADEQUATE DESCRIPTION OF NOISE REQUIRES MEASUREMENT OF OVERALL INTENSITY LEVEL AS WELL AS A DETERMINATION OF THE SPECTRUM. THE LATTER CONSISTS OF DIVIDING THE FREQUENCY COMPONENTS OF NOISE INTO OCTAVE OR 1/3 OCTAVE BANDS AND MEASURING THE INTENSITY LEVEL IN EACH BAND.

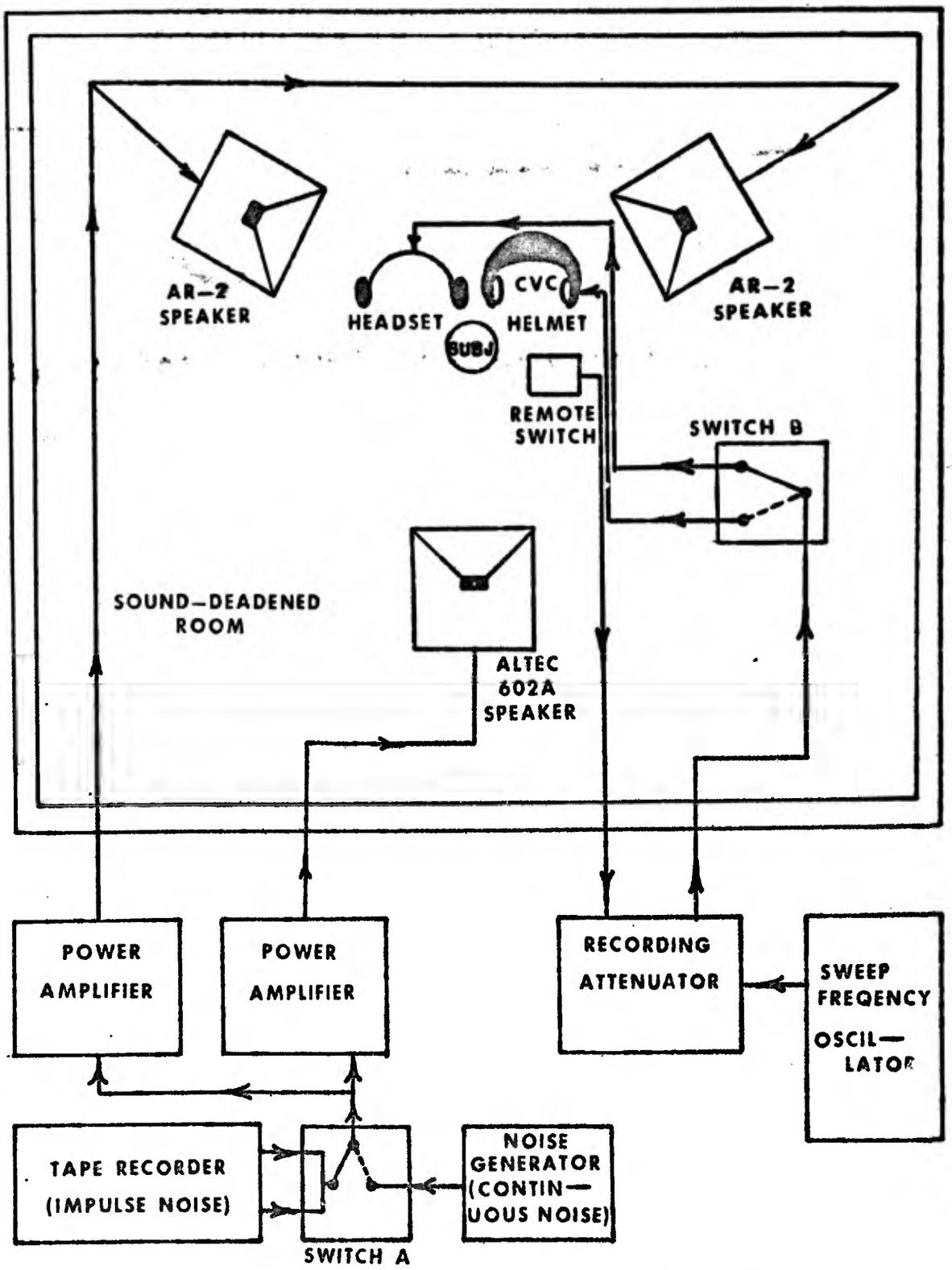

FIGURE 3: BLOCK DIAGRAM OF EXPERIMENTAL SITUATION.

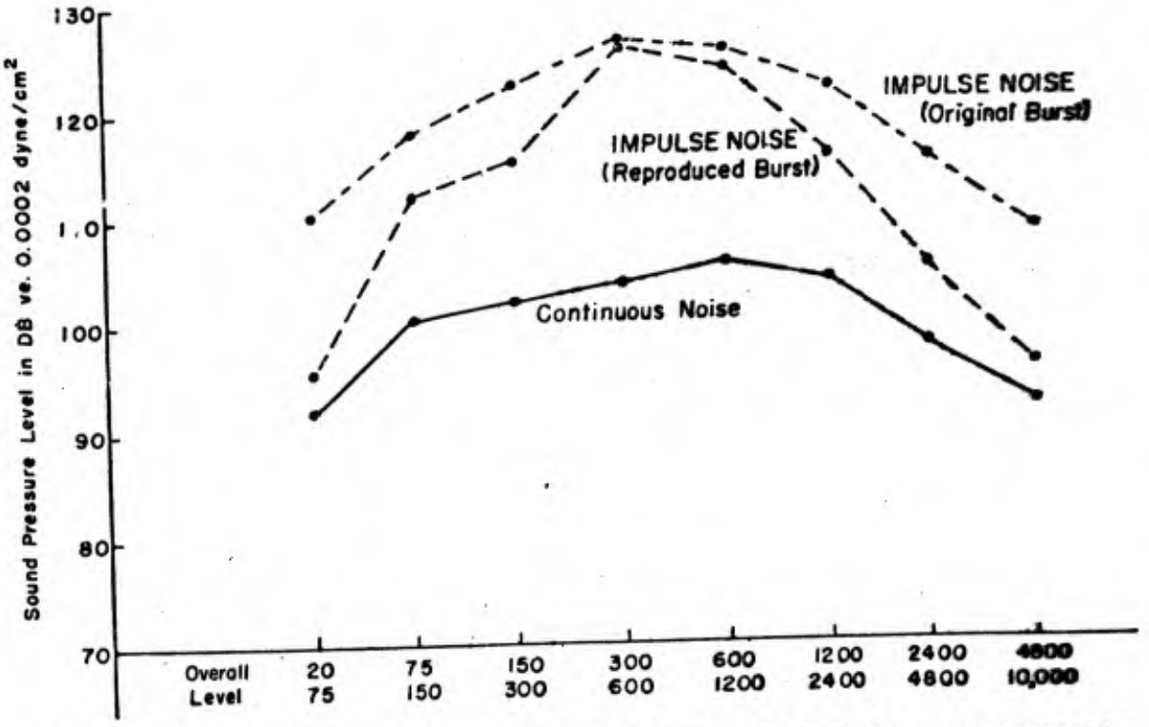

FIGURE 4: OCTAVE BAND ANALYSES OF ORIGINAL AND REPRODUCED IMPULSE NOISE AND CONTINUOUS NOISE.

THIS ANALYSIS IS SHOWN IN FIGURE 4 FOR AN ORIGINAL AND REPRODUCED BURST OF FIRING NOISE. THE OVERALL LEVEL OF CONTINUOUS NOISE WITHIN THE ROOM WAS READ ON THE SOUND LEVEL METER. PASSING THIS SIGNAL THROUGH THE OCTAVE-BAND NOISE ANALYZER GAVE THE CONTINUOUS NOISE SPECTRUM SHOWN IN FIGURE 4.

C. SUBJECTS

TEN WHITE ENLISTED MEN, 19 TO 23 YEARS OF AGE, VOLUNTEERED AS SUBJECTS FOR THE STUDY. THE RESULTS OF A STANDARD AUDIOMETRIC TEST GIVEN BEFORE THE EXPERIMENT INDICATED THAT ALL SUBJECTS HAD NORMAL HEARING. AN OTOLOGICAL EXAMINATION ALSO SHOWED NO EAR, NOSE, OR THROAT ABNORMALITIES.

D. DESIGN

EACH SUBJECT WAS INDIVIDUALLY TESTED IN 13 ONE-HOUR SESSIONS. THE INTERVALS BETWEEN SESSIONS RANGED FROM 24 TO 72 HOURS AND WERE BELIEVED TO BE LONG ENOUGH TO ALLOW COMPLETE RECOVERY OF THE HEARING LOSSES FROM

THE PRECEDING SESSIONS. INDEED, THE RANGE OF SESSION TO SESSION PRE-EXPOSURE THRESHOLD VARIABILITY FOR A GIVEN EAR WAS TYPICALLY SMALL (9 DB). THE FIRST HOUR WAS INTENDED TO FAMILIARIZE THE SUBJECT WITH THE TEST PROCEDURE AND INCLUDED NO NOISE EXPOSURE. A DIFFERENT COMBINATION OF THE 12 EXPERIMENTAL CONDITIONS (2 TYPES OF NOISE X 3 DURATIONS OF EXPOSURE X 2 EAR COVERINGS) WAS PRESENTED IN EACH OF THE FOLLOWING 12 SESSIONS. ONLY ONE EAR WAS EXPOSED AND TESTED FOR HEARING LOSS IN EACH SESSION, THE RIGHT AND LEFT EARS BEING USED ALTERNATELY ACROSS THE 12 EXPERIMENTAL SESSIONS. THE RIGHT EARS FOR HALF OF THE SUBJECT GROUP WERE ALWAYS EXPOSED IN THOSE CONDITIONS INVOLVING IMPULSE NOISE, AND THE LEFT EARS OF THESE SUBJECTS WERE TESTED ONLY UNDER CONTINUOUS NOISE CONDITIONS. FOR THE OTHER HALF OF THE SUBJECT GROUP, THE RIGHT EAR WAS ALWAYS TESTED IN THE CONTINUOUS NOISE CONDITIONS AND THE LEFT EAR TESTED IN THE IMPULSE NOISE CONDITIONS.

E. Procedure

IN THE FIRST SESSION, THE SUBJECT WAS INSTRUCTED IN THE USE OF THE SWITCH CONTROLLING THE ATTENUATOR AND GIVEN AN ASCENDING AND DESCENDING THRESHOLD TEST ON EACH EAR. THE ASCENDING TEST INVOLVED THRESHOLD DETERMINATIONS WHILE THE TEST-TONE WAS INCREASED FROM 100 TO 10000 CPS IN FREQUENCY. UNDER DESCENDING TEST CONDITIONS, THRESHOLDS WERE OBTAINED FOR THE TEST-TONE AS IT WAS DECREASED FROM 10000 TO 100 CPS. EACH ASCENDING AND DESCENDING TEST REQUIRED 11 MINUTES TO COMPLETE, DURING WHICH TIME THE SUBJECT CONTROLLED THE ATTENUATOR SO AS TO OSCILLATE BETWEEN JUST-HEARING AND JUST-NOT-HEARING THE TEST-TONE. DURING THE PRACTICE SESSION, THE TEST-TONE WAS FED THROUGH EITHER THE RIGHT OR LEFT PHONE OF A SET OF PERMADYNE EARPHONES (PDR-8) WHICH WERE MOUNTED IN DOUGHNUT CUSHIONS AND HELD IN A SPRING HEADBAND. THIS HEADSET WAS ALSO USED IN SUBSEQUENT TEST SESSIONS FOR BARE EAR EXPOSURES. IN THESE INSTANCES, THE SIGNAL WAS FED THROUGH THE EARPHONE OF THE TO-BE-EXPOSED EAR WHICH WAS GIVEN AN ASCENDING THRESHOLD TEST JUST BEFORE THE NOISE EXPOSURE. THE EARPHONE WAS THEN PUSHED BACK OFF THE EAR AND THE NOISE PRESENTED. AT THE END OF THE EXPOSURE, THE SUBJECT SLIPPED THE EARPHONE OVER THE EAR AND WAS GIVEN A DESCENDING THRESHOLD TEST. A PERIOD OF 10 SECONDS ELAPSED BETWEEN THE CONCLUSION OF THE NOISE EXPOSURE AND THE START OF THE DESCENDING TEST. THE EAR NOT BEING EXPOSED WAS SEALED WITH A COTTON-VASELINE PLUG AND COVERED WITH THE OTHER EARPAD OF THE HEADSET DURING THE ENTIRE TEST SESSION. WHEN THE CVC HELMETS WERE WORN, THE TEST-TONE IN THE THRESHOLD TESTING WAS FED THROUGH THE APPROPRIATE EARPHONE OF THE HELMET'S COMMUNICATIONS GEAR TO THE EAR UNDER STUDY PRIOR TO AND JUST AFTER THE NOISE EXPOSURE. DURING THESE SESSIONS, THE EAR NOT UNDER TEST WAS SEALED WITH A COTTON-VASELINE PLUG IN ADDITION TO THE HELMET EARPIECE.

2. Results

A. Losses related to frequency and exposure time

HEARING LOSSES FOR FREQUENCIES 250, 400, 500, 800, 2000, 3000, 4000, 6000, AND 8000 CPS, EXPRESSED AS DECIBEL DIFFERENCES BETWEEN

PRE- AND POST-EXPOSURE THRESHOLDS FOR EACH TONE, WERE DETERMINED FOR THE SUBJECT GROUP UNDER THE VARIOUS EXPERIMENTAL CONDITIONS. TABLE I SHOWS THE MEDIANS AND SEMI-INTERQUARTILE RANGES* OF THE HEARING LOSS DATA. IT IS INDICATED THAT THE MAGNITUDES AND VARIABILITY OF THRESHOLD LOSSES WERE GREATER FOR FREQUENCIES 1000 CPS AND ABOVE THAN FOR THOSE BELOW, IRRESPECTIVE OF DIFFERENCES IN EAR PROTECTION, EXPOSURE TIME, AND TYPE OF NOISE. THERE IS ALSO A GENERAL TREND FOR HEARING LOSS TO INCREASE WITH INCREASING EXPOSURE TIME. SEPARATE EVALUATIONS OF THIS TREND FOR EACH COMBINATION OF EAR PROTECTION AND TYPE OF NOISE CONDITIONS WERE ALL STATISTICALLY SIGNIFICANT ($P < .05$).**

B. COMPARISON OF HEARING LOSSES FOR CONTINUOUS AND IMPULSE NOISE

TABLE II SHOWS THE DIFFERENCES BETWEEN THE MEDIAN HEARING LOSSES FOR THE VARIOUS FREQUENCIES WHICH WERE PRODUCED BY CONTINUOUS AND IMPULSE NOISE FOR THE THREE EXPOSURE TIMES UNDER BARE EAR CONDITIONS. WITH FEW EXCEPTIONS, THRESHOLD IMPAIRMENTS FOR CONTINUOUS NOISE WERE GREATER THAN THOSE FOR IMPULSE NOISE FOR ALL EXPOSURE TIMES. EVALUATION OF THESE DIFFERENCES BY THE MANN-WHITNEY U-TEST FOR INDEPENDENT SAMPLES (13)*** INDICATED THAT THRESHOLD LOSSES IN THE RANGE 1500 TO 6000 CPS FOR 6-MINUTE EXPOSURES AND 2000 TO 6000 CPS FOR 12- AND 18-MINUTE EXPOSURES WERE SIGNIFICANTLY GREATER FOR CONTINUOUS AS COMPARED TO IMPULSE NOISE.

C. NOISE PROTECTION GIVEN BY CVC HELMET

THE AMOUNT OF NOISE PROTECTION GIVEN BY THE CVC HELMET WAS DETERMINED BY NOTING THE DIFFERENCES BETWEEN THE MEDIAN HEARING IMPAIRMENTS OCCURRING UNDER PROTECTED (CVC HELMET) AND UNPROTECTED (BARE EARS) CONDITIONS. TABLE III CLASSIFIES THESE DIFFERENCES BY FREQUENCY, TYPE OF NOISE, AND EXPOSURE TIME AND SUMMARIZES THE RESULTS OF A SIGN TEST (13) EVALUATION OF THE DIFFERENCES. IT IS SHOWN THAT THE CVC HELMET IN THE CONTINUOUS NOISE FIELD SIGNIFICANTLY REDUCED THE AMOUNT OF HEARING LOSS FOR FREQUENCIES 3000 TO 8000 CPS FOR 6-MINUTE EXPOSURES, FREQUENCIES

*THE SEMI-INTERQUARTILE RANGE (Q) IS A MEASURE OF VARIABILITY ABOUT THE MEDIAN OF A DISTRIBUTION OF DATA. SPECIFICALLY, IT DELIMITS ONE-HALF OF THE MIDDLE 50% OF SCORES ABOUT THE MEDIAN.

**THE JONCKHEERE DISTRIBUTION-FREE K-SAMPLE TEST FOR ORDERED ALTERNATIVES (8) WAS USED IN THESE ANALYSES. THE HEARING LOSSES FOR EACH SUBJECT, WHEN AVERAGED ACROSS ALL FREQUENCIES, SERVED AS THE RAW DATA IN THE COMPUTATIONS.

***FOR PURPOSES OF THIS STUDY, IT WAS ASSUMED THAT DIFFERENT EARS OF THE SAME SUBJECT WOULD REACT INDEPENDENTLY UNDER THE NOISE EXPOSURE CONDITIONS. SINCE DIFFERENT EARS OF THE SAME SUBJECTS WERE EXPOSED TO IMPULSE AND CONTINUOUS NOISE, THE TEST OF THE DIFFERENCES PRODUCED BY THESE TWO TYPES OF NOISE WAS BASED UPON A STATISTIC USING INDEPENDENT SAMPLES OF MEASUREMENT.

TABLE I

MEDIANS (M) AND SEMI-INTERQUARTILE RANGES (Q) OF HEARING LOSSES (IN DECIBELS [DB]) FOR PROTECTED AND UNPROTECTED EARS FOLLOWING VARIOUS EXPOSURE TIMES TO CONTINUOUS AND IMPULSE NOISE

UNPROTECTED EARS

	Continuous Noise						Impulse Noise					
	6 Min.		12 Min.		18 Min.		6 Min.		12 Min.		18 Min.	
Freq.	M	Q	M	Q	M	Q	M	Q	M	Q	M	Q
250	-4.0	5.0	0.5	4.0	-1.0	4.0	-5.3	6.0	-3.0	6.0	-1.0	3.5
400	-4.0	5.0	-1.0	2.5	0.0	0.5	0.0	2.5	-1.0	1.5	2.0	1.5
500	-2.0	6.0	-2.0	4.5	0.0	3.0	-1.5	2.0	-1.0	5.0	0.0	1.0
800	3.0	4.0	-1.5	3.0	8.0	4.0	-1.0	2.5	-1.0	5.0	4.0	3.2
1000	2.0	6.0	1.5	3.5	10.0	4.0	-1.5	2.5	4.0	2.5	4.0	2.5
1500	8.0	7.0	6.0	7.0	12.0	5.0	1.5	3.0	3.0	1.5	9.0	6.0
2000	10.0	6.0	16.5	4.5	19.0	5.0	5.0	2.5	10.0	5.0	10.0	3.5
3000	10.0	8.0	19.5	6.0	27.0	9.0	4.0	6.5	8.0	7.0	8.0	11.0
4000	20.0	4.0	22.0	10.0	31.0	7.0	5.0	5.0	7.0	8.0	20.0	11.0
6000	15.0	7.0	30.0	7.0	28.0	10.0	5.0	4.0	7.0	10.0	17.0	10.0
8000	21.0	6.0	27.5	8.0	29.0	8.5	14.0	11.0	20.0	13.0	29.0	7.0

PROTECTED EARS

	Continuous Noise						Impulse Noise					
	6 Min.		12 Min.		18 Min.		6 Min.		12 Min.		18 Min.	
Freq.	M	Q	M	Q	M	Q	M	Q	M	Q	M	Q
250	-1.5	3.0	-2.0	2.0	0.0	2.3	0.0	3.5	0.0	3.0	0.5	2.5
400	-0.5	1.7	-1.0	2.5	0.0	1.7	0.0	3.0	-0.5	5.0	1.0	4.0
500	0.5	2.5	-2.0	1.5	0.0	2.0	1.0	1.0	1.0	4.0	1.0	2.0
800	1.5	3.0	2.0	2.0	6.0	1.7	0.0	3.5	3.5	2.5	8.0	2.5
1000	4.0	3.3	0.0	2.7	8.0	4.7	1.0	3.0	3.5	4.5	7.0	7.0
1500	2.5	3.3	2.0	2.7	10.0	4.7	7.0	3.0	8.0	4.0	8.5	6.0
2000	5.0	3.0	5.0	2.5	9.0	3.5	5.0	7.0	10.5	11.0	5.0	7.5
3000	4.5	4.0	9.0	5.0	16.0	1.5	10.0	4.0	17.5	9.0	11.5	9.0
4000	10.5	4.5	11.0	4.7	21.0	6.0	6.0	5.0	10.0	4.0	8.0	3.7
6000	4.5	9.5	6.0	4.5	10.0	8.0	4.0	3.5	7.0	7.0	16.0	7.5
8000	13.0	8.0	9.0	9.0	25.0	7.0	12.0	9.0	25.0	6.5	32.5	10.0

NOTE: A NEGATIVE MEDIAN VALUE (-) INDICATES AN IMPROVED THRESHOLD RESPONSE FOLLOWING NOISE EXPOSURE.

TABLE II

DIFFERENCES BETWEEN MEDIAN HEARING LOSSES (IN DECIBELS /DB/) FOR CONTINUOUS AND IMPULSE NOISE FOR THREE EXPOSURE TIMES UNDER BARE EAR CONDITIONS

	Exposure Time (Min.)		
Frequency	6	12	18
250	1.3	3.5	0.0
400	-4.0	0.0	-2.0
500	-0.5	1.0	0.0
800	4.0	0.5	4.0
1000	3.5	-2.5	6.0
1500	6.5*	3.0	3.0
2000	5.0	6.5*	9.0*
3000	6.0*	11.5*	19.0**
4000	15.0**	15.0*	11.0*
6000	10.0*	23.0**	11.0*
8000	7.0	7.5	0.0

NOTE: Positive difference indicates that losses under continuous noise exceed those noted for impulse noise. Negative difference (-) indicates that losses under impulse noise were greater than those found for continuous noise.

*.01 < p < .05
**p < .01

TABLE III

DIFFERENCES BETWEEN MEDIAN HEARING LOSSES FOR PROTECTED (CVC HELMET) AND BARE EARS FOR THREE EXPOSURE TIMES TO CONTINUOUS AND IMPULSE NOISE

	Continuous Noise			Impulse Noise		
	Exposure Time (Min.)			Exposure Time (Min.)		
Frequency	6	12	18	6	12	18
250	-2.5	2.5	-1.0	-5.3	-3.0	-1.5
400	-3.5	0.0	0.0	0.0	-0.5	1.0
500	-2.5	0.0	0.0	-2.5	-4.0	1.0
800	1.5	-3.5	2.0	-1.0	-4.5	-4.0
1000	-2.0	1.5	2.0	-2.5	0.5	-3.0
1500	5.5	4.0	2.0	-5.6	-5.0	0.5
2000	5.0	11.5*	10.0*	0.0	-0.5	5.0
3000	5.5*	10.5*	9.0*	-6.0	-9.5*	-3.5
4000	9.5*	11.0*	10.0*	-1.0	-3.0	12.0*
6000	10.5*	24.0**	18.0**	1.0	0.0	1.0
8000	8.0*	18.5**	4.0	2.0	-5.0	-3.5

NOTE: Positive differences indicate that losses for unprotected ears exceeded those for protected ears. Negative (-) differences indicate that losses for protected ears exceeded those for unprotected ears.

*.01 < p < .05
**p < .01

2000 TO 8000 CPS FOR 12-MINUTE EXPOSURES AND FREQUENCIES 2000 TO 6000 CPS FOR 18-MINUTE EXPOSURES. ON THE OTHER HAND, DIFFERENCES BETWEEN UNPROTECTED AND PROTECTED EAR EXPOSURES TO THE IMPULSE NOISE SHOW THAT THE CVC HELMET GAVE LITTLE PROTECTION AGAINST SUCH NOISE. INDEED, ONLY ONE FREQUENCY (4000 CPS) FOR AN 18-MINUTE EXPOSURE SHOWS A SIGNIFICANT REDUCTION IN HEARING LOSS WHEN WEARING THE HELMET. ANOTHER FREQUENCY (3000 CPS) AT 12 MINUTES OF EXPOSURE EVEN SHOWS A SIGNIFICANT INCREASE IN HEARING LOSS WHEN WEARING THE HELMET IN THIS TYPE OF NOISE FIELD.

EXPERIMENT II
RECOVERY FROM TEMPORARY HEARING LOSS AT 4000 CPS

1. METHODOLOGY AND APPARATUS

A. GENERAL TESTING CONDITIONS

THE PURPOSE OF THIS EXPERIMENT WAS TO STUDY THE RECOVERY FROM THE TEMPORARY HEARING LOSSES CAUSED BY EXPOSURES TO THE 12 NOISE CONDITIONS OF EXPERIMENT I. A TONE OF 4000 CPS WAS CHOSEN FOR STUDY SINCE IT WAS REPRESENTATIVE OF THOSE FREQUENCIES IN EXPERIMENT I WHICH SHOWED MARKED HEARING LOSSES UNDER THE SPECIFIED CONDITIONS OF NOISE EXPOSURE. THE PROCEDURE FOR THRESHOLD TESTING WAS THE SAME AS IN EXPERIMENT I EXCEPT THAT THE TEST-TONE WAS FIXED AT 4000 CPS FOR THE ENTIRE STUDY. THRESHOLDS FOR THIS TONE WERE TRACED JUST BEFORE NOISE EXPOSURE AND IN A 20-MINUTE PERIOD AFTER THE CESSATION OF THE NOISE. THE DECIBEL DIFFERENCE BETWEEN THE PRE-EXPOSURE AND INITIAL POST-EXPOSURE THRESHOLD VALUES INDICATED THE IMMEDIATE THRESHOLD LOSS AND REPRESENTED THE STARTING POINT OF THE RECOVERY PROCESS. THIS DECIBEL DIFFERENCE TOGETHER WITH THOSE NOTED BETWEEN THE PRE-EXPOSURE THRESHOLD AND THRESHOLDS OBTAINED AT VARIOUS TIMES DURING THE 20-MINUTE PERIOD FOLLOWING EXPOSURE WERE PLOTTED AS THE RECOVERY CURVE FOR EACH NOISE CONDITION.

THE INSTRUMENTATION USED IN THRESHOLD DETERMINATION AND FOR THE GENERATION OF THE VARIOUS NOISE CONDITIONS IN EXPERIMENT II WAS THE SAME AS THAT USED IN EXPERIMENT I.

B. SUBJECTS

THE SUBJECTS WERE 10 WHITE ENLISTED MEN (DIFFERENT FROM THOSE USED IN EXPERIMENT I) WHOSE AGES RANGED FROM 19 TO 22 YEARS. ALL SUBJECTS HAD NORMAL HEARING AS MEASURED BY A STANDARD AUDIOMETRIC TEST GIVEN PRIOR TO THE EXPERIMENT. OTOLOGICAL EXAMINATIONS OF THE SUBJECT GROUP SHOWED NO SIGNIFICANT EAR, NOSE, OR THROAT DEFECTS.

C. DESIGN AND PROCEDURE

EACH SUBJECT WAS INDIVIDUALLY TESTED IN ONE PRACTICE SESSION FOLLOWED BY 12 EXPERIMENTAL SESSIONS; THE LATTER CONFORMED TO THE DESIGN CONDITIONS SPECIFIED IN EXPERIMENT I. THE PRACTICE SESSION ENABLED

SUBJECTS TO TRACE THEIR 4000 CPS THRESHOLDS (I.E., VARY SIGNAL INTENSITY SO AS TO OSCILLATE BETWEEN JUST-HEARING AND JUST-NOT-HEARING THE TONE) FOR 15 MINUTES WITH EACH EAR AND INCLUDED NO NOISE EXPOSURE. HEADSETS WERE WORN DURING THIS PERIOD, THE TONE BEING FED TO THE EARPIECE COVERING THE EAR UNDER TEST. HEADSETS WERE ALSO WORN IN SUBSEQUENT EXPERIMENTAL SESSIONS INVOLVING BARE EAR EXPOSURES TO NOISE. UNDER SUCH CONDITIONS, THE 4000 CPS TONE WAS SUPPLIED TO THE TO-BE-EXPOSED EAR AND THRESHOLDS WERE TRACED FOR A 5-MINUTE PERIOD BEFORE THE NOISE EXPOSURE. THE EARPIECE COVERING THE EAR WAS THEN PUSHED ASIDE BY THE SUBJECT AND THE NOISE PRESENTED. AFTER THE NOISE STOPPED, THE SUBJECT SLIPPED THE EARPHONE OVER THE EXPOSED EAR AND AGAIN TRACED HIS THRESHOLD FOR THE 4000 CPS TONE CONTINUOUSLY FOR A PERIOD OF 20 MINUTES.* THE EAR NOT BEING TESTED IN THESE SESSIONS WAS FILLED WITH A COTTON-VASELINE PLUG AND COVERED WITH THE OTHER EARPHONE IN THE HEADSET FOR THE ENTIRE PERIOD. SIMILARLY, WHEN CVC HELMETS WERE WORN IN THE EXPERIMENTAL SESSIONS, 4000 CPS THRESHOLDS WERE TRACED FOR 5 MINUTES BEFORE AND 20 MINUTES AFTER NOISE EXPOSURE. THE 4000 CPS TONE WAS SUPPLIED TO THE EAR UNDER TEST BY USING THE APPROPRIATE EARPIECE OF THE HELMET'S COMMUNICATIONS GEAR. THE NON-TESTED EAR WAS FILLED WITH A COTTON-VASELINE PLUG IN ADDITION TO BEING COVERED WITH THE OTHER EARPIECE IN THE HELMET ASSEMBLY.

2. Results

A. Effect of Exposure Time on Recovery

DECIBEL DIFFERENCES BETWEEN 4000 CPS THRESHOLDS OBTAINED JUST BEFORE THE NOISE AND FROM 10 SECONDS TO 20 MINUTES AFTER THE NOISE WERE DETERMINED FOR EACH SUBJECT AND NOISE EXPOSURE CONDITION. THE MEDIAN DIFFERENCES FOR THE SUBJECT GROUP FOUND 10 SECONDS AFTER NOISE EXPOSURE AS WELL AS FOR EACH MINUTE OF THE 20-MINUTE RECOVERY PERIOD ARE PLOTTED IN FIGURE 5 FOR ALL COMBINATIONS OF NOISE, DURATION, AND PROTECTION CONDITIONS. THE CURVES SHOWN IN THIS FIGURE INDICATE THAT THE THRESHOLD LOSSES IMMEDIATELY AFTER NOISE EXPOSURE AS WELL AS THE RECOVERY TIME FROM SUCH LOSSES BECOME GREATER WITH INCREASING EXPOSURE TIME. IT IS ALSO APPARENT FROM THE SLOPES OF THESE CURVES, THAT RECOVERY WAS RAPID WITHIN THE FIRST 2 MINUTES FOLLOWING NOISE EXPOSURE. BEYOND 2 MINUTES, THE RATE OF RECOVERY DECREASED APPRECIABLY.

B. Recovery from Continuous and Impulse Noise Exposure

INSPECTION OF THE RECOVERY CURVES SHOWN IN FIGURE 5A AND 5B SHOWS THAT CONTINUOUS NOISE PRODUCED GREATER IMMEDIATE HEARING LOSSES FOR 4000 CPS THAN IMPULSE NOISE FOR THE 3 EXPOSURE TIMES UNDER BARE EAR CONDITIONS. RECOVERY FROM THE THRESHOLD LOSSES DUE TO IMPULSE NOISE FOR 6- AND 12-MINUTE EXPOSURES WAS FASTER THAN THAT FOR CONTINUOUS NOISE. FOR 18-MINUTE DURATION, EXPOSURES TO BOTH CONTINUOUS AND IMPULSE NOISE REQUIRED MORE THAN 20 MINUTES FOR COMPLETE RECOVERY.

*ABOUT 10 SECONDS ELAPSED BETWEEN THE END OF THE NOISE EXPOSURE AND THE START OF THE THRESHOLD TRACING.

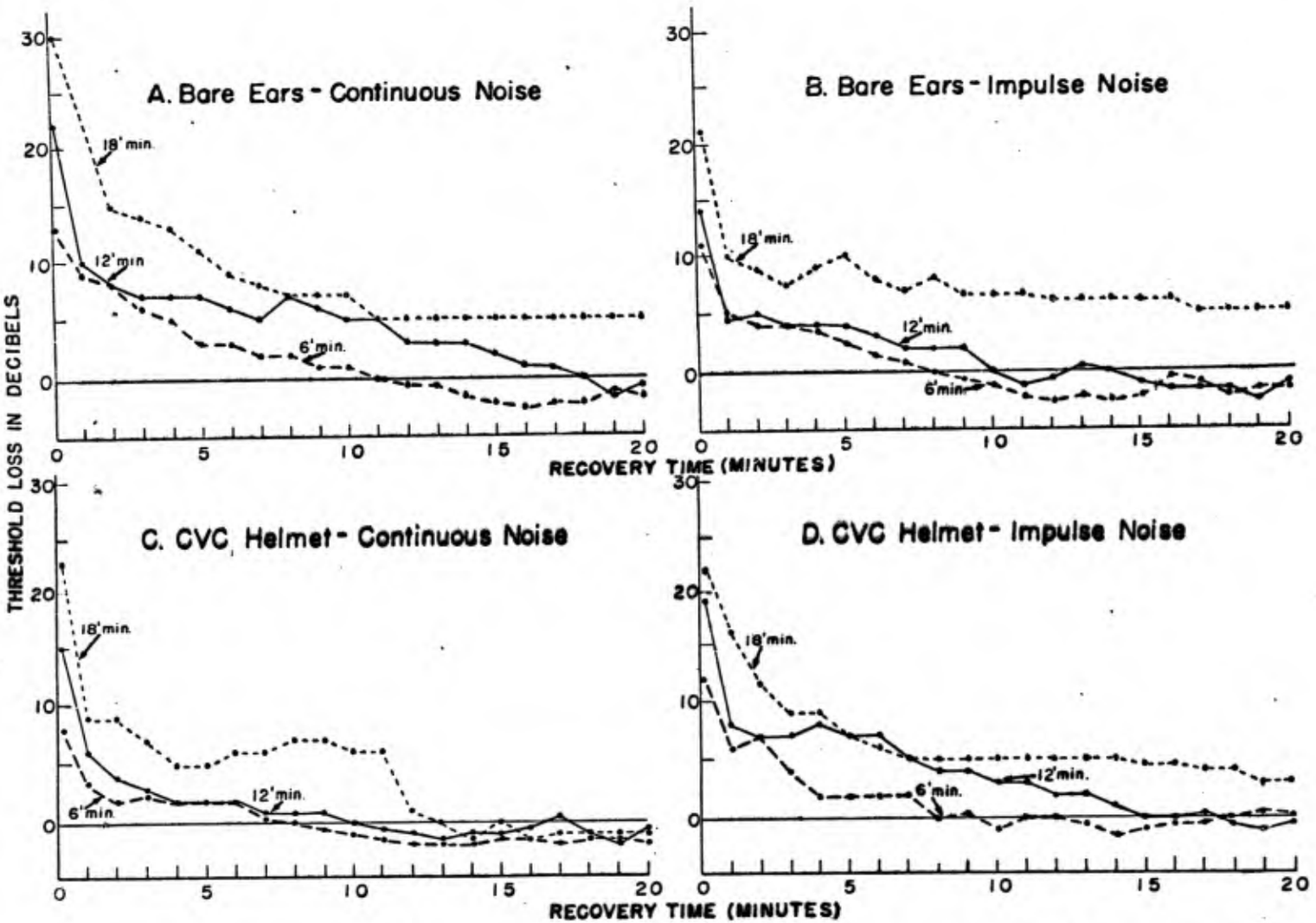

FIGURE 5: RECOVERY CURVES OF 4000 CPS THRESHOLD LOSSES FOR BARE AND PROTECTED (CVC HELMET) EARS FOLLOWING VARIOUS EXPOSURE TIMES TO CONTINUOUS AND IMPULSE NOISE. EACH POINT REPRESENTS THE MEDIAN VALUE FOR 10 SUBJECTS.

C. Effect of Helmet Protection on Recovery

Recovery data for protected ears (CVC helmet) following various durations of continuous noise (Fig. 5c) show immediate threshold shifts and recovery times which are reduced in comparison to those obtained for bare ear exposures under the same conditions (Fig. 5a). On the other hand, the slight differences between the curves shown in Figure 5b and Figure 5d for impulse noise indicate that the helmet had little effect in decreasing the magnitudes of threshold losses and subsequent recovery times for bare ear exposures to such noise.

D. Comparison of Percentage Recovery Data for Various Exposure Conditions

To show more clearly the recovery aspects of this study, percentage recovery scores for 1, 3, 5, and 8 minutes after exposure were computed for each subject for each experimental condition. The percentage recovery scores represent the differences between the threshold losses found immediately after the noise exposure and at each of the specified times during the recovery period, divided by the immediate threshold loss. Table IV shows the median percentage recovery scores for the subject groups at 1, 3, 5, and 8 minutes after bare ear exposures to continuous and impulse noise of various durations. With only one exception, the recovery scores noted at different times following exposure to impulse noise are all greater than those shown for continuous noise. However, an evaluation of the individual subject scores by the Mann-Whitney U-test (13) indicated that the differences between recovery scores for continuous and impulse noise were statistically significant in only one instance (See Table IV).

A comparison of the percentage recovery scores for protected (CVC helmet) and bare ear exposures to continuous noise of various durations is shown in Table V. Based upon the results of a sign test (13) performed

TABLE IV
COMPARISON OF MEDIAN PERCENTAGE RECOVERY SCORES FOR BARE EAR EXPOSURES TO CONTINUOUS AND IMPULSE NOISE OF VARIOUS DURATIONS

Time After Exposure (min.)	6 min.			12 min.			18 min.		
	Cont.	Impl.	Diff.	Cont.	Impl.	Diff.	Cont.	Impl.	Diff.
1	38	45	-7	53	65	-12	20	60	-40**
3	50	61	-11	68	61	7	45	61	-16
5	77	82	-5	69	70	-1	59	70	-11
8	84	91	-7	75	78	-3	70	75	- 5

**$P < .01$

TABLE V

COMPARISON OF MEDIAN PERCENTAGE RECOVERY SCORES FOR BARE AND PROTECTED (CVC HELMET) EAR EXPOSURES TO CONTINUOUS NOISE AND IMPULSE NOISE OF VARIOUS DURATIONS

Time After Exposure (min.)	6 min.			12 min.			18 min.		
	CVC	Bare	Diff.	CVC	Bare	Diff.	CVC	Bare	Diff.
Continuous Noise									
1	44	38	6	63	53	10	60	20	40**
3	64	50	14	80	68	12	72	45	27*
5	70	77	-7	89	69	20*	87	59	28*
8	98	84	14	96	75	21*	91	70	21*
Impulse Noise									
1	48	45	3	50	65	-15	52	60	-8
3	50	61	-11	48	61	-13	65	61	4
5	70	82	-12	59	70	-11	80	70	10
8	88	91	-3	68	78	-10	79	75	4

*$.01 < p < .05$

**$p < .01$

ON THE INDIVIDUAL SUBJECT DATA, SIGNIFICANT DIFFERENCES BETWEEN PERCENTAGE RECOVERY SCORES FOR PROTECTED AND BARE EARS WERE NOTED FOR 1, 3, 5, AND 8 MINUTES FOLLOWING CONTINUOUS NOISE EXPOSURE OF 18 MINUTES. THE DIRECTION OF THESE DIFFERENCES INDICATED THAT THE RATE OF RECOVERY FROM HEARING LOSS INCURRED WHILE WEARING A HELMET, IN CONTINUOUS NOISE WAS FASTER THAN WHEN NO EAR COVERING WAS USED. SIGNIFICANT INCREASES IN THE RATES OF RECOVERY FOR PROTECTED EAR CONDITIONS WERE ALSO NOTED FOR 5 AND 8 MINUTES AFTER EXPOSURE TO 12 MINUTES OF CONTINUOUS NOISE. NO SIGNIFICANT DIFFERENCES BETWEEN BARE AND PROTECTED EAR RECOVERY SCORES WERE FOUND, HOWEVER, FOR 6-MINUTE EXPOSURES.

DIFFERENCES BETWEEN THE MEDIAN PERCENTAGE RECOVERY SCORES FOR PROTECTED AND BARE EAR EXPOSURES TO VARIOUS DURATIONS OF IMPULSE NOISE ARE ALSO SHOWN IN TABLE V. APPLICATION OF SIGN TESTS (13) TO THE INDIVIDUAL SUBJECT DATA INDICATED THAT NONE OF THE DIFFERENCES BETWEEN BARE AND PROTECTED EAR CONDITIONS WERE STATISTICALLY SIGNIFICANT. HENCE, AS COMPARED WITH BARE EAR EXPOSURES, THE HELMET DID NOT FACILITATE RECOVERY FROM HEARING LOSSES FOLLOWING EXPOSURE TO IMPULSE NOISE.

DISCUSSION

THE FINDINGS OF EXPERIMENTS I AND II SUPPORT THE CONCLUSION THAT FOR VARIOUS EXPOSURE TIMES TO A GIVEN AMOUNT OF NOISE ENERGY, CONTINUOUS

NOISE PRODUCES GREATER THRESHOLD LOSSES THAN IMPULSE NOISE. INDEED, BOTH FOR SIZE OF IMMEDIATE THRESHOLD LOSS AND FOR AMOUNT OF RECOVERY AT VARIOUS TIMES AFTER EXPOSURE, IMPULSE NOISE IS LESS DETRIMENTAL TO HEARING ACUITY THAN AN EQUIVALENT AMOUNT OF CONTINUOUS NOISE. WHILE THESE RESULTS ARE IN AGREEMENT WITH A PREVIOUS INVESTIGATION (14), THEY MAY NOT APPLY TO EXTREMELY INTENSE IMPULSES OF NOISE. AS SPEITH AND TRITTIPOE (14) HAVE NOTED, SHORT-TERM EXPOSURES TO REPEATED BLASTS REACHING PEAK LEVELS OF 160 DB OR MORE MAY PRODUCE MORE HEARING DAMAGE THAN THE SAME AMOUNT OF CONTINUOUS NOISE ENERGY. IT SHOULD BE NOTED HERE THAT PEAK INTENSITY LEVELS OF 160 DB OR MORE ARE NOT UNCOMMON IN MILITARY SITUATIONS. THE FIRING LEVELS OF THE 76MM, 90MM, AND 105MM FIELD PIECES, FOR EXAMBLE, ARE ALL ABOVE 160 DB (1).

ANOTHER LIMITATION TO GENERALIZING THE PRESENT FINDINGS CONCERNS THE RELATIONSHIP BETWEEN TEMPORARY AND PERMANENT HEARING LOSS. IS THE SAME AMOUNT OF TEMPORARY HEARING LOSS PRODUCED BY CONTINUOUS AND IMPULSE NOISE ASSOCIATED WITH THE SAME AMOUNT OF PERMANENT HEARING DAMAGE WITH PROLONGED EXPOSURES? RECENT EVIDENCE (15) HAS INDICATED THAT THE EXTENT OF TEMPORARY THRESHOLD CHANGES FOLLOWING A DAY'S EXPOSURE TO CONTINUOUS NOISE IS SURPRISINGLY CLOSE TO THE MAGNITUDES OF PERMANENT HEARING LOSSES NOTED AFTER 10-YEARS EXPOSURE TO THE SAME TYPE OF NOISE. SUCH AN EVALUATION HAS NOT AS YET BEEN CONDUCTED FOR IMPULSE TYPES OF NOISE.

THE SECOND BASIC FINDING OF THE PRESENT STUDY IS THE DIFFERENTIAL NOISE PROTECTION OFFERED BY THE CVC HELMET TO CONTINUOUS AND IMPULSE TYPES OF NOISE. AS COMPARED WITH THE THRESHOLD LOSSES OCCURRING FOR UNPROTECTED EARS IN A CONTINUOUS NOISE FIELD, THE CVC HELMET SIGNIFICANTLY REDUCED THE AMOUNT OF IMMEDIATE THRESHOLD SHIFT AND INCREASED THE RATE OF RECOVERY FOLLOWING EXPOSURE TO SUCH NOISE. IN CONTRAST, THE PROTECTION GIVEN BY THE HELMET TO IMPULSE NOISE WAS NEGLIGIBLE. THIS RESULT WAS PROBABLY DUE TO THE SOUND ATTENUATING PROPERTIES OF THE HELMET AND THE DIFFERENCES IN SPECTRA BETWEEN THE TWO TYPES OF NOISE. TABLE VI SHOWS THE OCTAVE BAND INTENSITIES FOR THE CONTINUOUS AND REPRODUCED IMPULSE NOISE TOGETHER WITH THE SOUND ATTENUATION GIVEN BY THE CVC HELMET WHEN AVERAGED FOR THE FREQUENCIES WITHIN EACH BAND. SUBTRACTING THE HELMET'S ATTENUATION FROM THE CONTINUOUS NOISE BY OCTAVE BANDS YIELDS INTENSITY VALUES WHICH ALL FALL BELOW 100 DB. SUCH VALUES HAVE ONLY LIMITED CAPABILITY FOR PRODUCING HEARING LOSS, ESPECIALLY FOR THE EXPOSURE TIMES USED IN THE PRESENT STUDY. FOR IMPUDSE NOISE, HOWEVER, THE HELMET'S ATTENUATION WOULD STILL LEAVE INTENSITY VALUES, PARTICULARLY IN THE LOW AND MIDDLE BANDS, WHICH ARE OVER 100 DB AND STILL HIGH ENOUGH TO CAUSE SIGNIFICANT HEARING LOSSES.

THE INEFFECTIVE PROTECTION PROVIDED BY THE CVC HELMET TO MACHINE-GUN NOISE MAY BE GENERALIZABLE TO OTHER TYPES OF HELMETS AND OTHER KINDS OF WEAPON NOISE. THIS IS BASED UPON TWO FINDINGS. THE FIRST IS THAT THE ATTENUATION PROPERTIES OF THE CVC HELMET ARE QUITE SIMILAR TO THOSE FOUND IN OTHER TYPES OF ARMOR AND AIRCRAFT CREWMENS' HEADWEAR (11). THE SECOND IS THAT THE OCTAVE BAND INTENSITIES NOTED IN THE NOISE SPECTRA FOR MOST WEAPONS EQUALS OR EXCEEDS THOSE GENERATED BY THE 30 CAL. MACHINE-GUN (1).

TABLE VI

ATTENUATION OF CONTINUOUS AND IMPULSE NOISE LEVELS (IN DB) BY CVC HELMET

	Octave Band Limits in Cycles Per Second						
	75 150	150 300	300 600	600 1200	1200 2400	2400 4800	4800 10000
Contin. Noise	101	102	105	107	105	98	90
CVC Attenuation	5	7	7	10	17	25	30
Resultant Level	96	95	98	97	88	73	60
Impulse Noise	112	115	122	121	115	114	96
CVC Attenuation	5	7	7	10	17	25	30
Resultant Level	107	108	115	111	98	89	66

The temporary hearing losses found in the present investigation and mentioned throughout this discussion were generally greater for tones above 1000 cps than for those below. This result was expected, since exposure to wide spectrum noise (such as the continuous and impulse noise used here) results in threshold losses particularly for the higher frequencies of sound (6, 12). Bare ear exposures to the continuous noise, however, caused maximum losses at either 4000 or 6000 cps. For comparable exposure conditions, impulse noise produced maximum losses at 8000 cps. Unfortunately, there was no clear indication in the present study as to what factor or factors might be causing this result.

Summary and Conclusions

In the first of two studies, temporary hearing losses for frequencies 250 to 8000 cps were noted for bare and protected ears (CBC helmet) following 6-, 12-, and 18-minute exposures to continuous and impulse (recorded 30 cal. machine gun fire) noise of comparable energy level. Apparent threshold losses for both types of noise were greater for frequencies above 1000 cps than for those below. These impairments tended to increase with increasing exposure time. Under bare ear conditions, continuous noise caused greater hearing loss than impulse noise, irrespective of exposure time. Wearing the CVC helmet in the presence of continuous noise, however, significantly reduced the amount of

THRESHOLD LOSS OCCURRING UNDER BARE EAR EXPOSURES. IN CONTRAST, THE HELMET GAVE NEGLIGIBLE PROTECTION AGAINST IMPULSE NOISE.

A SECOND EXPERIMENT STUDIED A 20-MINUTE RECOVERY PERIOD FOR 4000 CPS HEARING LOSSES FOLLOWING EXPOSURE TO THE NOISE CONDITIONS OF THE FIRST INVESTIGATION. UNDER BARE EAR EXPOSURES, RECOVERY FROM CONTINUOUS NOISE WAS SLOWER THAN THAT FOR IMPULSE NOISE, PARTICULARLY FOR THE LONGER EXPOSURE TIMES. WEARING THE HELMET INCREASED THE RATE OF RECOVERY FROM CONTINUOUS NOISE EXPOSURES BUT HAD LITTLE EFFECT UPON THE THRESHOLD RECOVERY FROM LOSSES DUE TO IMPULSE NOISE.

ALTHOUGH THERE WERE CERTAIN LIMITATIONS, THE RESULTS OF THE TWO STUDIES SUGGEST TWO BASIC CONCLUSIONS:

1. FOR VARIOUS EXPOSURE TIMES TO A GIVEN AMOUNT OF NOISE ENERGY, CONTINUOUS NOISE CAUSES GREATER TEMPORARY HEARING LOSS FOR UNPROTECTED EARS THAN DOES IMPULSE NOISE.

2. RELATIVE TO THE LOSSES OCCURRING UNDER BARE EAR EXPOSURES, THE CVC HELMET PROVIDES GREATER PROTECTION AGAINST CONTINUOUS NOISE THAN AGAINST IMPULSE NOISE.

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APPENDIX

COMPUTATION OF AVERAGE AMOUNT OF SOUND ENERGY CONTAINED IN 1 MINUTE OF IMPULSE NOISE

APPENDIX

COMPUTATION OF AVERAGE AMOUNT OF SOUND ENERGY CONTAINED IN 1 MINUTE OF IMPULSE NOISE

The computational procedure consisted of weighting the pressure ratio equivalents* of the burst and inter-burst decibel levels by the respective amounts of burst and inter-burst time which occurred in a 1-minute presentation of impulse noise. The decibel levels of the machine gun bursts averaged 128 db, which corresponded to a pressure ratio of 2.512×10^6. The inter-burst decibel level was 75 db which was equal to a pressure ratio of 5.623×10^3. Since 136 bursts of gunfire occurred per minute and each burst lasted .06 seconds, $136 \times .06$ or 8.16 seconds represented the total burst time per minute. Subtracting 8.16 seconds from 60 seconds gave 51.84 seconds, the total amount of inter-burst time per minute. The weighting operation consisted of multiplying the burst pressure ratio by the burst time per minute, i.e., $(2.512 \times 10^6) \times (8.16)$, and the inter-burst pressure ratio by the inter-burst time, i.e., $(5.623 \times 10^3) \times (51.84)$, which gave products of 20.50×10^6 and 291.50×10^3 respectively. Adding these products together and dividing by 60 yielded a pressure ratio (3.47×10^5) which reflected the average amount of sound energy contained in 1 minute's presentation of impulse noise. Converting this pressure ratio back to decibel level gave a value of 111 db.

*Decibel values are logarithmic expressions which usually require conversion to other forms, e.g., pressure ratios, before they can be handled in arithmetic computations. Tables for converting decibel levels to pressure ratios (and vice-versa) are found in The General Radio Handbook of Noise Measurement, General Radio Co., Concord, Massachusetts, 1956.

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